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THE GIPSY MOTH AS A FOREST INSECT,
WITH SUGGESTIONS AS TO ITS CONTROL.

BY

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PREVENTING SPREAD OF MOTHS.

LABORATORY.

(*At Melrose Highlands, Mass.*)

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THE GIPSY-MOTH SITUATION: PAST AND PRESENT.

It has been said of the gipsy moth that the caterpillar is almost omnivorous so far as foliage is concerned, and the early reports published by the State Board of Agriculture of Massachusetts abound in references confirmatory of this statement. It is in fact incontrovertible, from the mass of evidence furnished by these reports as well as by the contemporaneous accounts in the press, that the gipsy moth was formerly almost unique amongst injurious insects in its ability to destroy all sorts of vegetation. Upon the occasion of its historic outbreak in Medford and Malden, beginning about 1889, and again in the larger outbreak following a few years after the extermination work was concluded in 1900, not only forest, shade, and ornamental trees but orchards, gardens, and fields were defoliated and devastated. And when the food supply was exhausted the starving caterpillars, by force of numbers alone, constituted a veritable plague, rendering the streets almost impassable to pedestrians, massing upon and entering houses, and infesting the bedrooms, the kitchens, and even the dining tables as well as all outdoors.

It is needless to state that these conditions no longer prevail. Caterpillars there are, during their season; egg masses in varying abundance are everywhere to be found in neglected woodlands, and thousands of dead and dying trees stand as evidence that unless it be rendered still further innocuous the gipsy moth is still a very living factor to be considered in the future of American forestry. But the accounts of its earlier depredations seem all but incredible when compared with conditions to-day. It is no longer prominent as a field and garden pest.

¹ A consideration of the parasites of the gipsy moth (*Porthetria dispar* L.), the "wilt" disease, and the natural resistance of certain species of trees to attack by the gipsy moth, as applied to the management of forests.

As an orchard insect it is not infrequently eclipsed by the American tent caterpillar. Even the forests have suffered less than early predictions would have led one to expect. It is certain that the situation has become measurably improved within recent years.

CAUSES OF THE IMPROVED CONDITIONS.

This obvious improvement is in part only apparent and in part very real and due to a variety of causes. The apparent amelioration is due to the fact that the gipsy moth is at present most active in a belt of towns beyond the limits of the densely populated metropolitan area. Were Boston's parks again to be infested as formerly; were the forests in the Middlesex Fells, for example, to be defoliated, a wave of remonstrance would arise which might be heard halfway across the continent. But a thousand acres of forest in the sparsely populated and financially poor towns 30 to 50 miles away may be repeatedly defoliated and ultimately destroyed without creating more than a ripple in comparison. And this latter is precisely what is taking place at the present time. It will be necessary to wait until in its slow progress the gipsy moth invades another great metropolitan area before popular interest will be aroused to an extent comparable to that existing in Massachusetts a few years ago.

The real amelioration so noticeable in the metropolitan district, and distinctly in evidence everywhere, is due to at least four main causes: (1) The perfection and standardization of the methods for artificial repression; (2) the death of a large proportion of the more susceptible trees or their removal from the infested woodlands; (3) the importation of parasitic and predatory insect enemies; and (4) the development of the "wilt" disease.

As it is intended at this time to consider the gipsy moth strictly as a forest insect no mention need be made of the methods for artificially suppressing it. On account of their expense these methods can not be used in forests other than those which it is desired to protect for æsthetic and sentimental reasons.

RESULTS OF PARASITE IMPORTATION.

There are about 30 species of insect enemies of the gipsy moth which appear to be of importance in checking its increase in Europe and Japan. All of the promising species have been imported and colonized under more or less satisfactory conditions in America. Not all have successfully accommodated themselves to their new environment. About one-third of the total appear to have done so and to be steadily increasing in efficiency in accordance with their powers of multiplication and dispersion.

It was hoped that more of them would acclimatize themselves; it was feared that the number might be less. On the whole, the results

are decidedly satisfying, and the State of Massachusetts and the United States Department of Agriculture have no cause to regret having undertaken the unexpectedly formidable task of parasite importation. Within a territory centering a little to the northward of Boston, it may be conservatively stated that fully 50 per cent of the eggs, caterpillars, or pupæ of the gipsy moth, in the aggregate, were destroyed by imported parasites in 1912. The territory over which the imported insect enemies have spread is not yet very extensive, but it is extending notably from year to year, and there is every reason to believe that the mortality to which the gipsy moth is already subjected in this central portion of the infested area will eventually be considerably increased throughout its whole extent. Some additional work will be done toward assisting in the dispersion of certain species, and it may be that a new attempt will be made to import under more satisfactory conditions certain others which appear not to have established themselves as the result of earlier attempts. Otherwise the work of parasite importation may be considered as completed.

THE "WILT" DISEASE OF THE GIPSY MOTH.

More than to the parasites, more than to the perfection of the methods of artificial suppression, the amelioration in conditions is due to the "wilt" disease. This is a malady similar to or suggestive of the flacherie of the silkworm. According to recent investigations it is due to parasitism by a bacterium which has been described under the name of *Gyrococcus flaccidifex* by its discoverers, Messrs. Glaser and Chapman, working under the direction of Dr. W. M. Wheeler, of the Bussey Institution. While it is not positively proved that this bacterium is the cause of the disease, there are no good grounds for doubting and many for believing that it is. Confirmation is expected as the result of further cooperative investigations now under way by the Bureau of Entomology and the Bussey Institution.

Although we know very little of the bacterium, we know much of the malady. According to the most trustworthy observers it first appeared about 1903 or 1904 in certain of the worst infested forests, and by 1907, when the present writer first became associated with the gipsy-moth work, it was everywhere in evidence throughout the infested area. It seemed slightly to increase in the years immediately following and to have reached a climax about 1911. At the present time, fortunately, there is nothing to indicate that it is at all likely to become much if any less effective in the immediate future.

We do not yet know how the caterpillars originally become infected, but once infected there is hardly room for doubting that the organism itself is conveyed from one generation to another through the egg. Simple infection is by no means sufficient to cause death. On

the contrary, if conditions are otherwise favorable an infected caterpillar will live, complete its transformations, and (it is believed) transmit the germs of the disease directly to its offspring. Under these circumstances generation could follow generation, and in the course of time the race of gipsy moths might gradually be purged of the disease, so that eventually only a few individuals would carry it.

This would all be changed were the infected caterpillars to become weakened through any other cause. Under such circumstances an apparently healthy individual will sicken and die, and in a surprisingly short time the entire contents of its body will be resolved into a black liquid containing countless myriads of the germs of disease where before there were but few. Death is particularly likely to ensue upon the topmost twig of the tree, and the disintegrated body of the victim, breaking of its own weight, permits the black poison to defile the foliage below. Another caterpillar feeding upon this foliage contracts the disease and, provided it also be weakened through any other cause, it quickly dies, and the process is repeated.

It is very evident that the more abundant the caterpillars chance to be in a given forest the greater the chance that the disease will be thus transmitted; the more these caterpillars chance to be weakened through a lack of suitable food the more likely they are quickly to succumb and transmit the malady to their fellows. It thus results that when a forest is threatened with defoliation by infected caterpillars the disease becomes epidemic and spreads with astounding rapidity.

A yet more important cause for the development of the "wilt" than partial defoliation is to be found in unfavorable food. It used to be easy to rear caterpillars in the laboratory upon lettuce, for example, when they were free from the taint of the disease, but it is practically impossible to do so to-day, if American eggs are used. With foreign eggs, collected from a locality where the wilt is not prevalent, this did not prove to be the case in the course of experiments recently conducted at the Gipsy Moth Parasite Laboratory, which it is proposed to repeat the present year. Nor is lettuce an exception among foods. The same may be said of practically all herbaceous plants, and, fortunately, of a considerable variety of trees and shrubs.

Herein lies the most potent cause for the less destructive character of the gipsy moth in recent years, according to the opinion of the writer—an opinion which it is expected will be abundantly confirmed in the course of the coming summer. And herein lies the real secret of the practical resistance of certain species of trees to gipsy-moth attack.

ARTIFICIAL UTILIZATION OF THE "WILT" DISEASE.

It seems necessary to emphasize the foregoing statement that the resistance of certain species of trees is directly due to the susceptibility of caterpillars, feeding upon the foliage of these trees, to death through the "wilt" disease, and thus incidentally to emphasize the very great importance of the disease itself. Since this disease is believed to result from parasitism by a specific bacterium, the proposition of increasing its efficiency through infecting the caterpillars artificially with cultures of the bacterium at once suggests itself.

This possibility is largely precluded if equal emphasis be laid upon the real character of the disease, so far as we are able to determine it, either through intensive study of the organism believed to be responsible or through observations upon its activities in the field.

At the present time wherever caterpillars are to be found, infected caterpillars have been found also upon every occasion when search for them has been made. Furthermore, even though the infection were proved to be wind-borne, as has been contended—and there is room for doubt regarding this most essential fact—every particle of reliable evidence indicates that slightly infected caterpillars remain reasonably healthy. The condition of the caterpillars upon the artificially protected trees along the roadsides in localities where an epidemic of the disease prevails in the main body of the forest is, or ought to be, sufficient evidence of this. Notwithstanding that these caterpillars are forced to feed upon trees which have been sprayed, and notwithstanding that through artificial suppression alone are they prevented from stripping the trees, those which escape death amid the various dangers by which they are artificially encompassed remain remarkably healthy, and with comparatively rare exceptions there is an increase in numbers of the fresh egg masses each fall over the number which escaped the creosote brush the preceding spring.

Rather elaborate experiments have been carried on in the past to determine whether the disease could be practically transmitted through infected food, and with one notable exception those who have conducted such experiments have concluded that artificial utilization of the disease in this manner is impracticable. If the writer is not mistaken it was Dr. Roland Thaxter, of Harvard University, a specialist of high standing upon the vegetable parasites of insects, who was the first actually to experiment along this line, and who was the first to be convinced of its futility. In 1908 Dr. Herbert Johnson, working for the State of Massachusetts in cooperation with Harvard University, conducted an elaborate series of field experiments to test this theory, but with no more promising results.

Further investigation and experimentation were conducted cooperatively by the State of Massachusetts and Harvard University

under the direction of Dr. E. A. Mark and Dr. Theobald Smith, working more or less independently, and still the results were negative. The present writer, in connection with the work of parasite importation, conducted experiments of a similar nature but with the usual outcome. The difficulty in every case was due to the fact that it was impossible to secure healthy caterpillars for either the experiment or its check. It made no difference whether the caterpillars were fed with the infected food or not, large numbers would die in any event, and there seemed to be no noticeable difference between the mortality in the experiments and in the checks.

It remained for Mr. William Reiff, at one time a laboratory assistant in the Bussey Institution, to claim success where others had failed. His experiments were, in their essential characters, like those of his predecessors. He fed some caterpillars upon an unfavorable food, and they contracted the disease and died, exactly as had resulted in all other recent attempts to rear caterpillars in the laboratory from American eggs. When the sick and dead individuals were placed upon badly infested trees in the field a mortality was noticed among the other caterpillars in the vicinity. The fact was cheerfully ignored that a similar mortality might be observed in every other locality where the same degree of infestation prevailed, and no attempt was made systematically to determine exactly what happened in these other places. In this most important respect the experiments conducted by Mr. Reiff differed from those conducted by Dr. Johnson.

Such a series of check observations has been made the past season, quite incidentally, in connection with the field-observation work as conducted by Mr. A. F. Burgess of the Bureau of Entomology. The final results of this work for the season are not yet available, but the writer, who has personally visited the majority of the observation points, of which perhaps 20 per cent chanced to be in the immediate vicinity of disease plantings of the summer before, has been absolutely unable to distinguish a single point of difference between the treated and the untreated localities. In every badly infested locality complete or partial defoliation with all its attendant consequences resulted. The severity of the injury differed notably in different localities, as was to be expected, but if extreme instances were to be cited it would not be difficult to select localities where no disease was planted in which conditions at the close of the season were very much better than in others where plantings had been made.

Nor is there anything unusual anywhere in the infested territory to differentiate conditions this fall from those prevailing a year or two ago. In fact it is the writer's personal impression that rather more pine has been seriously injured in 1912 than in 1911, and that the condition of the oak is worse than he has ever seen it before. In short, nothing whatever that is tangible has yet come to the attention of

anyone associated with the Bureau of Entomology which can be used in support of the contention that the disease may be rendered more efficient through artificial dispersion. The extensive experiments conducted by the State of Massachusetts in 1912, in pursuance of its policy to investigate thoroughly every possible method of ridding its forests of the gipsy moth, would appear to have resulted exactly as did the earlier and less elaborate series conducted by Dr. Johnson and others.

NATURAL CONTROL OF THE GIPSY MOTH ABROAD.

A large portion of the past two years has been spent by the writer abroad in studying the gipsy moth in its original habitat. The objects of this over-sea work were several. It was desired more exactly to determine the part played by the parasites in holding the gipsy moth in check in the European forests and to ascertain whether all the important species of parasites had been discovered. Were promising new species found, attempts were to be made to ship large quantities to America for experimental colonization. Above all, it was hoped to learn whether the assumption upon which the parasite work had originally been undertaken was well grounded; that is, whether all the factors responsible for the natural control of the gipsy moth in the European forests were present and active in America, saving only the parasites. The results of this work are in part supplemented and in part confirmed by the observations of Mr. L. H. Worthley, who has spent the better part of a year abroad, and in part they are pertinent to this discussion.

It was found that the invasion of the greater part of Europe by the gipsy moth some three to seven years ago had spent its force, and that, although small numbers of the insect might be found in nearly every oak forest visited in Italy and Germany, it was found abundant in very few. It was difficult to ascertain definitely what had occurred to check this general invasion, but it is certain that a disease similar in all its external manifestations to the American "wilt" (and also to the well-known and beneficent "wipfelkrankheit" of the nun moth) had prevailed in many localities, including some in Russia, Italy, and Germany. It seemed to have been epidemic in all of the localities which had been badly infested by the gipsy moth.

It was also evident that following the enormous decrease in numbers brought about by this epidemic there was nothing like the phenomenal increase of the straggling remainder so frequently observed in America. Instead, when an innocuous minimum was reached this desirable condition was maintained for an indefinite and sometimes for a protracted period. It appeared highly probable—and this

probability was supported by definite confirmatory evidence—that the failure of the moth immediately to increase was due as much as anything to the parasites; and a wholly unexpected and phenomenal rate of parasitism was found to prevail in some localities. Incidentally several species of parasites until then unrecognized as important or promising were found and large numbers were shipped to America.

The rôle played by the parasites, however, was obviously less important than had been assumed when the work of parasite importation was inaugurated. Generally speaking, it appeared that though the increase of the moth was prevented or retarded through parasitism, it was principally if not invariably through disease that an actual outbreak was checked.

This was borne out by the circumstances associated with two local outbreaks in southern Italy: One in Sicily, in the extensive cork-oak forest of San Pietro, near Caltagirone, and the other in the communal forest of the town of Gioia Tauro, in Calabria. In both of these localities, and particularly in the latter, the parasites were abundant and varied. In neither were they able to prevent the rapid increase of the moth, much less to bring about a decrease. In both the defoliation of a large portion of the forest was absolutely complete, and in neither was the "wilt" disease operative.

The conditions in the forest of San Pietro were the more interesting and instructive because the invasion there was of no less than 12 years' standing. At no time, according to the statements of the local authorities, had the entire forest been defoliated at once, but the invasion would sweep back and forth over it, so that the trees were defoliated about every second or third year.

Here in this Sicilian forest all the amazing stories told of the gipsy moth upon the occasion of its historic outbreak in Malden and Medford were abundantly substantiated. There were no streets and very few houses, but there were a few gardens, fields, orchards, and vineyards, and an abundance of wild plants, shrubby and herbaceous. Of them all, wild and cultivated, hardly a dozen species were immune from attack. There were places where at times the ground was black with the caterpillars as they came out of the forest, which no longer afforded them either food or protection, and invaded the fields and open spaces. Here the combination of burning sand and blazing sun resulted in the agonizing death of myriads, and their dead bodies could have been swept up by the bushel.

Neither in 1911 nor in 1912 was a single caterpillar dying of the wilt observed. Parasites were abundant each year, destroying approximately 90 per cent, which was far from sufficient to prevent increase. Each year the millions which died of starvation and

exposure dried up without showing traces of the decomposition invariably associated with the "wilt."

As a result, in the worst infested portions of the forest there would be very few eggs, but the caterpillars would always be remarkably healthy the next season, and as the parasites would be attracted to the more badly infested parts of the forest the rate of increase elsewhere would be simply astounding.

In the Calabrian forest the invasion had not passed beyond its preliminary stages in 1911, but by 1912 it had reached its maximum. Here conditions were the same, except that as the surrounding fields offered better protection from the glaring sun the caterpillars coming out of the forest lived longer and did more damage to the crops. The trees in both forests were absolutely stripped of foliage whenever there were sufficient caterpillars and not left, as they are so commonly in America, where the disease is prevalent, with a sprinkling of partly eaten leaves. All kinds seemed to suffer alike. There were no conifers except a few cypress (related to and with foliage very like our white cedar) which grew along an agave hedge, bordering the Sicilian forest. These were stripped as bare as the oaks.

In no locality other than these two, whether European or American, has the writer been able to find the gipsy moth unaccompanied by disease. It is the prevalence of such extraordinary conditions and their similarity to those which prevailed in America before the development of the disease which serve to convince him that the present improved conditions are so largely due to the presence of the "wilt" disease.

FOREST CONDITIONS AS A FACTOR IN CONTROL.

It is obvious, even to the casual American traveler, that in most European countries applied forestry is developed to an unfamiliar extent. The forests are treated with an intelligent respect for their requirements and a careful consideration for their continued well-being rarely approached in America. It may even be said that they are among the most stable of European institutions. Nations have risen and fallen, but policies of forest management adopted half a thousand years ago are used as a working basis in those same forests to-day.

This being the case, it logically follows that if the gipsy moth had ever threatened the European forests to anything like the extent that it threatens American forests to-day, methods of forest management would have been evolved which, either consciously or unconsciously, would have taken its destructive tendencies into consideration. After having studied the gipsy moth in these forests both Mr. Worthley and the writer are much inclined to the opinion that something very like this has taken place.

To a large extent the European, and particularly the German, forests differ radically from those within the area infested by the gipsy moth in America. Oak, so common as a coppice growth in America, is relatively little grown in Germany, and when successfully grown the forest bears little resemblance to the typical American coppice. It has been stated repeatedly that oak is not materially injured by the gipsy moth in Germany, even though the trees are occasionally stripped, because they refoamate and seem to retain a fair amount of vigor. Notwithstanding this statement they are frequently in bad condition, particularly in forests which more nearly approximate in character the American coppice. For example, in a large tract near Neusalz-Oder many oaks were dead or dying. Various causes were adduced for their death, such as attack by a species of *Agrilus*, attack by a fungous disease, attack by a leaf-roller, *Tortrix viridiana*, etc., and the circumstance that they had been defoliated several years before by the gipsy moth was not considered as responsible for their condition. It is significant, and suggestive of the existence of a parallel, that following defoliation by the gipsy moth in America the trees frequently refoamate, but are subsequently destroyed by a species of *Agrilus*, or by a fungous disease, or by something else than simply defoliation.

Oak in Germany is apt to become stag-headed—that is, to die prematurely from the top; and it also happens frequently in America that when trees have been once or twice defoliated by the gipsy moth and then protected from further injury they are affected in the same way. In America we have been able to determine and define the cause of the injury through a comparison of conditions outside and inside the infested territory, but in Germany, where the entire country may be said to be infested, such comparison is not so easy.

There are numerous other points which might be brought forward in support of the contention that in Europe the liability of certain types of forests to serious injury through occasional defoliation by the gipsy moth has long been taken into account and that, albeit unconsciously, methods of forest management have been modeled accordingly. Without attempting to reason out the whys and wherefores the pioneer foresters were content to recognize the simple fact that certain types of forests might not be grown under certain conditions or at all, and whether this were due to the character of the soil, or to the climate, or to the presence of an insect like the gipsy moth matters not.

Similar recognition of similar drawbacks to the cultivation of certain types of forest is probably what we must come to in America. It stands forth as the main result of the European observations that in the European forests the gipsy moth is held in check by three

agencies which did not exist in America at the time of the earlier and most alarming invasions—

1. The parasites.
2. The disease.
3. The character of the forests.

The parasites are promising to become about as efficient here as in the European forests, and it must not be forgotten that no more has been claimed for them than that they would render the gipsy moth as innocuous here as in its original habitat.

The disease, too, is about as efficient here as it is abroad.

Perhaps it is not too much, then, to demand that forest conditions in America be made to conform a little more nearly to those of the countries in which the gipsy moth is native, particularly to those of Germany.

This does not by any means imply the adoption of European forest methods en masse, but rather that the forests be given a little better attention and that provision be made for the actual or inevitable invasion by the gipsy moth through the elimination of those trees most likely to be injured and their replacement by others less susceptible and not infrequently more valuable. As a matter of fact this removal and replacement is taking place automatically in the territory that has been longest infested, but the natural process is too often accompanied by unnecessary destruction of other trees and unnecessary pecuniary loss.

RELATIVE SUSCEPTIBILITY OF AMERICAN FOREST TREES TO GIPSY MOTH ATTACK.

As has been stated, at the time when the first real invasion by the gipsy moth in the United States was at its height it was believed that scarcely any forest, shade, or fruit tree was resistant to its attack. And, as has been explained, the appearance of disease, following a period of uninterrupted increase of the moth, was accompanied by a change in this respect. That this change was very largely due to the disease is further indicated by the similarity of the conditions prevailing in certain Sicilian and Calabrian forests to-day to those prevailing in Medford and Malden in 1889.

The relative susceptibility of certain trees to injury and the relative immunity of others is therefore very largely due to, and dependent upon, the presence of disease. But since the disease is everywhere and bids fair to remain until possibly the gipsy moth is freed of its taint through a long series of generations passed under ideally healthy and favorable surroundings, there seems to be no reason why the necessary dependence should not be placed in it without fear of serious consequences.

At the same time the writer is averse to committing himself to the extent of stating positively that the methods of forest management to be suggested further on will invariably prove successful. He wishes to emphasize the truth as he sees it, that the relative freedom from injury of certain types of forest is dependent upon the "wilt," and that their continued well-being will largely depend upon the persistence of this malady.

He wishes further to emphasize his belief that an increase in the efficiency of the parasites will add to the variety of the forests which may be cultivated to advantage, but that it will not result in protection to all the types which at present are to be found in the area of infestation. The suggestion that experiments be conducted to determine the practicability of the "reserve-tree" method of cultivating oak is made only on the assumption that the parasites will eventually render more efficient aid than at present and in a less limited portion of the infested territory.

In 1908 Mr. A. H. Kirkland, in his third annual report as superintendent of work against the gipsy and brown-tail moths, first called attention to the apparent resistance of white pine unless associated with hardwood trees. A year later Mr. L. H. Worthley, his acting successor, published in the next report the results of experiments which showed that this was indeed the case, and that pure stands of pine might be protected at a very reasonable expense.

Partly in pursuance of this idea, and partly independently, Messrs. D. M. Rogers and A. F. Burgess, of the Bureau of Entomology, after observing the activities of the moth in the field, concluded that in addition to pine most of the other conifers, and certain hardwood trees as well, might be considered as sufficiently resistant to escape serious injury. Ash, hickory, and maple were mentioned, and recommendation was made jointly in Bulletin 87 of this bureau that such trees be planted in place of those which were destroyed.

These recommendations, made in 1910, were succeeded by further observations by employees of the Bureau of Entomology and the Massachusetts State forester's office with the result that by the fall of 1911 several important additions had been made to the list.

Exact information, however, was lacking, and because of the obvious need for it a series of investigations was inaugurated under the direction of Mr. Burgess. These were so planned as to demonstrate not only what happened when caterpillars were confined to certain sorts of food indoors, but exactly what happened following invasion of different types of forest out of doors. More than 250 observation points were selected, representative of every type of pure and mixed forest which could be easily located within the infested area. In addition to pure stands of pine, oak, and birch, for example,

mixed stands of oak and pine, birch and pine, oak and birch, etc., were selected.

A circle 100 feet in diameter was laid off around a central tree in the midst of the forest selected, every tree included was numbered, and notes were made covering its species, size, general condition, and degree of infestation. The total number of egg masses to be found within the circle was recorded, and their increase or decrease from year to year, together with the actual extent of injury resulting in cases of bad infestation, was to be taken as the measure of resistance offered by that particular type of forest.

Although the work is not yet complete, the results already secured are too pertinent and valuable to be reserved until its conclusion.

Rather for convenience than because the proposed classification is altogether natural the more common shade and forest trees of New England may be separated into groups in accordance with their susceptibility to injury.

The first of these groups consists of those trees upon which the moth following its establishment normally increases to the point of complete or nearly complete defoliation. After the first defoliation the moth's numbers may be very greatly reduced or they may remain practically the same. In the one case one or more years may elapse before defoliation is repeated. In the other, the forest may be defoliated for several years in succession. In either case the trees are likely to be severely injured and to die.

This group, so far as known, is composed exclusively of the various oaks, with the possible but not proved exception of the shrubby species. These may be considered as representing the most favored food plants of the gipsy moth.

The second group consists of those trees which appear to be especially favorable to the increase of the moth immediately following its establishment. Almost always, however, at about the time when defoliation would result were the colony to remain healthy, it receives a setback. The trees are rarely completely stripped, and though they may be from one-half to three-fourths defoliated for several successive years, death rarely follows.

The most notable representatives of this group are several of the tree willows and the gray birch. It is possible that some other trees will eventually be included; but none other so commonly encountered in the territory at present infested by the gipsy moth will compare directly with birch or willow. These, through the protection which they afford to incipient colonies of the gipsy moth, act as incubators or breeders.

In the third group are to be placed those trees upon which the gipsy moth rarely increases to the extent usual upon gray birch or willow. Upon some it will increase until a fair degree of infestation

results, but rarely to the point of noticeable defoliation. Upon others it will barely hold its own, and upon a few there will be a decrease in abundance following any considerable degree of accidental infestation. These trees are what is here called resistant, and nearly all of them are practically that, so long as the "wilt" remains as efficient as it is at present.

In this group are to be placed the pines; the spruces; in all probability fir; hemlock, with scarcely a doubt, though it is notably more favorable than pine as a food plant; the junipers and cedars; doubtfully larch; some, but perhaps not all, of the poplars; chestnut; probably beech; yellow birch, black birch, and probably paper birch; apparently all the species of hickory; butternut; sycamore; American elm, and probably the other species of elm; apparently hackberry; sassafras; catalpa; the various species of ash; black locust and honey locust; black cherry and bird cherry; probably mountain ash; all the indigenous and probably the European species of maple, although the Norway maple is more liable to attack than others; boxelder; tupelo; horse-chestnut; ailanthus; tulip tree, and undoubtedly many other of the less commonly planted shade and ornamental trees.

A few of the more common trees have not yet been definitely placed, notably basswood or linden, ironwood, and hop hornbeam.

RELATIVE SUSCEPTIBILITY OF MIXED FORESTS.

It would thus appear that in a territory in which both disease and parasites, or disease alone, is prevalent the gipsy moth becomes peculiarly an enemy of oak, and this is true in so far as pure stands of trees are concerned, or of isolated trees. It is not so true of mixed stands, however, as was pointed out by Mr. Kirkland and by Mr. Worthley in respect to pine mingled with hardwood, and these mixed stands may generally be considered just a little more resistant than would be a pure stand of the least resistant tree and considerably less resistant than a pure stand of the most resistant tree which goes to make up any considerable portion of the mixture. Thus a pine and oak forest is slightly less liable to injury than a pure stand of oak and much more liable than a pure stand of pine. The same might be said of an oak and hickory mixture or one of oak and chestnut. The reason is that the caterpillars, increasing uninterruptedly upon oak, will finally be forced to leave it and will strip other trees upon which they would not increase to anything like a similar extent if they were forced to feed upon them for generation after generation. They do not always do this, it is true, but they do it very often, particularly when the oak is abundant and scattered evenly throughout the forest.

Since hemlock is better liked than pine by the caterpillars, a mixed growth of oak and hemlock is much more likely to be destroyed completely than a mixed growth of oak and pine; and since gray birch is not so favorable a food plant as oak, a birch and pine mixture is not nearly so likely to suffer as a mixed stand of oak and pine.

Apparently no fear need be felt as to the safety of any mixture whatever of which all the component parts could be considered as resistant if they were standing in pure growth. As to the greater resistance of an oak tree when standing surrounded by chestnut and hickory, as compared with another of the same species and vigor surrounded by oak, there is room for further investigation. It can only be said that the protection thus afforded to oak through being associated with other trees is not particularly striking.

RELATION OF UNDERBRUSH TO THE FOREST.

It is interesting, in connection with the relative resistance of forest trees, to note that the sprouts and, to a less extent, the seedlings, are not so liable to injury as are larger trees of the same species. This is true even of pine, unless the writer has misinterpreted his field observations.

It is also true that for the most part the common species of shrubs to be found growing as underbrush in a forest are unfavorable as food for the gipsy moth—that is to say, they may be classed with the resistant species of trees. It is certainly logical and, to that extent, reasonable to suppose that underbrush will be found to play quite an important part in the protection of the forest. Caterpillars falling from trees in a pure stand of oak devoid of underbrush will find their way back to oak and be little the worse for the adventure. Caterpillars falling in a similar manner in a forest full of underbrush will not find their way back so readily, and the eating of strange food for a time will render them less resistant to disease, more likely to die, and thereby more likely to transmit the germs of disease to their fellows.

It is a subject well worthy of further study and experimentation and one to which it is hoped to devote considerable attention in the course of the coming year, the more so since it has special bearing upon the suggestion that oak might possibly be protected by adopting the method of cutting so as to leave reserve trees.

RELATIVE RESISTANCE OF DIFFERENT TREES OF THE SAME SPECIES.

It would appear from numerous observations that certain individual trees (of red oak, for example) are much better able to withstand the attack of the gipsy moth than others of the same species growing in the same wood lot. These trees, although they are subjected to the same degree of defoliation, will live when all around

them die and even take on new life and vigor through coming into a larger share of light and space. It is yet to be determined whether these trees are more resistant or whether, through standing in some favored pockets of richer soil, they simply survive through the possession of a more vigorous constitution.

It is undoubtedly true that vigorous, rapidly growing trees are more resistant than other trees of the same species less vigorous and less rapidly growing. Thus oak trees around the border of an infested wood lot, with more room to expand their roots and branches, not infrequently live when all or nearly all the more crowded individuals in the depths of the wood lot die. It is also true that isolated trees withstand a greater degree of defoliation than those in dense growth.

Advantage seems to have been taken of this principle in the method of growing oak formerly in vogue in Germany, for, if the writer is correctly informed, the finest and largest oaks in the Empire are grown more or less isolated and parked. When the relative immunity of young sprouts is also considered, a very logical reason is suggested for the fact that the method of leaving reserve trees, scattered over a territory devoted principally to the growth of sprouts or coppice, finds so much favor in certain parts of Europe. These reserve trees are left practically isolated in the forests which have come to the writer's personal attention, and the sprouts, for which there is a ready market, unfortunately lacking in America, are cut at quite frequent intervals.

SUGGESTIONS FOR THE MANAGEMENT OF FOREST LANDS WITH REFERENCE TO THE GIPSY MOTH.

It is by no means to be understood that because of the gipsy moth all the oak in this country is foredoomed to destruction, but attention must be called to what is undoubtedly the truth, that unless parasitism or disease, or something else not at present recognized as a variable factor in the natural control of this pest, develops to an extent unknown in either America or Europe, pure and mixed stands of oak will be seriously injured. Not only is the oak itself liable to injury, but also other trees mixed with it.

It is yet too soon to state definitely whether, in localities where there is no oak, other trees may not act as breeders of the moths to an equally disastrous extent. For instance, the paper birch in the north woods may so foster it as to bring about the defoliation of adjacent spruce. The results of field-observation work in occasional bits of forest in the infested territory where spruce and birch occur are not in themselves sufficient to settle the question, because conditions so far from the large body of boreal forest can not be considered

as really typical. So far as they go, however, they indicate that the gipsy moth is not to be feared outside the range of the oak or in forests inside that range provided the oak, and possibly one or two other species of unimportant trees, be eliminated.

There are, therefore, two phases of the complex problem of gipsy-moth control in forests which must be considered. First, how best to eliminate the oak and secure its replacement by other and, if possible, more valuable trees; and, second, how best to protect the oak from serious injury in localities where little else can be grown to advantage.

In a large portion of the area at present infested by the gipsy moth the solution is almost absurdly simple. This is the natural home of the white pine, one of the most valuable timber trees to be found in the whole Temperate Zone. In a way the oak is an interloper. Over a large part of New England the white pine was once preeminent, and it would become so again were the country to be deserted by civilized man. The pine reproduces freely, if given half a chance, but there are thousands of acres in the aggregate in which a natural reproduction of pine is being retarded, destroyed even, through the mere circumstance that the oak chanced to secure a running start, by sprouting, when the land was last cut over. The German forester who would permit such conditions to prevail would be considered hopelessly, even criminally insane. Under such circumstances oak is to be considered as a weed, and the advent of the gipsy moth as a blessing when, as sometimes happens, it takes the oak and leaves the pine. If it would always do just that and nothing more its progress might be watched with a certain degree of complacency. But it does not always stop at that and, what is worse, injudicious cutting not infrequently results in greater damage than would be done by the gipsy moth itself. The larger pines are apt to be cut or broken down, and the smaller ones, unable to compete with the rapidly growing oak sprouts, are quickly in no better condition than before.

The natural program, therefore, in every pine and oak mixture, is so to eliminate the oak as to afford the pine a better opportunity to take possession of the ground. How this may best be accomplished depends entirely upon the individual characteristics of any particular wood lot. And, furthermore, it is strictly a problem in applied forestry and one for the forester, not for the entomologist, to solve.

In a great many localities where the white pine does not grow naturally, or in which it has been destroyed through injudicious cutting and extensive forest fires, there is to be found a stand of oak mingled with other hardwoods. In these forests the solution is not reached quite so easily or so satisfactorily. Chestnut (saving only

for the possible injury by the blight), hickory, paper birch, sugar maple, and ash all find conditions greatly to their liking in one or another part of New England, and all are desirable substitutes for oak. There are certainly some, and probably numerous localities in which, through nothing more than the exercise of a little care and intelligent management, the oak may be removed and its natural replacement by these other hardwoods may be secured with a minimum of expense.

It is in the pure stands of oak, or in those of oak mingled with much less valuable trees, all too frequently to be found throughout the infested area, that the problem becomes acute. Here the land must be allowed practically to go to waste, or planting must be resorted to, or else some attempt must be made to maintain a growth of oak. The most simple method would seem to be the leaving of reserve trees. The chances at present are that this may not work very well, but unless the relief which we have every reason to expect through the further development of the parasites be denied us, there is a chance that in the near future it will prove to be a fairly satisfactory, cheap, and eventually remunerative alternative to permitting the forests to be entirely destroyed. It must not be forgotten that when the oaks are left to die from the gipsy-moth attack they very rarely sprout, and a pure oak stand is apt to degenerate into a thicket of gray birch or something even less intrinsically valuable. If the oak be thinned in advance of the gipsy-moth invasion the sprouts will be resistant for a period of years at least, perhaps until the parasites become so efficient that they will protect the stand of reserve trees. It is even possible, if the thinning be done far enough in advance of the invasion, that the reserve trees will have increased sufficiently in vigor to resist the attack of the moth until the parasites shall have multiplied sufficiently to hold it in check.

All these suggestions are to be treated as such and as nothing more. The author is no forester and can not pretend to recommend, but only to suggest. He has had the advantage, however, of four years' study of the insects injurious to American forests under the direction of the foremost forest entomologist in America, and through subsequent study of the gipsy moth in America and abroad has reached certain pretty definite conclusions. The gipsy moth is distinctly a menace to our forests, but it is really no more to be feared than any one of several forest insects native to this country. If the situation be rightly viewed, and a serious attempt be made to cope with it, it is certain that the results will redound not only to the benefit of the forests in general but to that of the country at large.

THE IMMEDIATE REQUIREMENTS OF THE SITUATION.

The immediate requirements of the situation are that the work be conducted in a hearty spirit of cooperation among all concerned. For the purpose of solving the problems associated with the elimination of oak and its replacement by other and, if possible, more valuable trees the Bureau of Entomology has allied itself with the United States Forest Service and hopes also to continue in hearty accord with the various State foresters most immediately concerned. The further investigation of the "wilt" disease will be conducted by the Bureau of Entomology and the Bussey Institution working together. Additional information concerning the relative resistance of various trees standing singly, or in pure or mixed growth, will be compiled by the Bureau of Entomology, which will also concern itself to discover exactly what progress is being made by the imported parasites and predatory enemies. These lines of investigation, observation, and research are all being directed with one single end in view, how best to protect the forest.

Of great importance, also, is the work intended to restrict the spread of the gipsy moth beyond the boundaries of New England. A certain amount of natural spread can not be prevented, especially through wind, but it is hoped entirely to eliminate the danger of an immensely more rapid spread through artificial channels, upon nursery stock, forest products, etc., shipped from infested to noninfested territory. It is also hoped considerably to retard the slow and inevitable natural dispersion, even though it is impossible entirely to prevent it.

The natural progression of the moth to the westward, which is the most to be feared and also the easiest to retard, will be more effectively controlled if the woodland colonies along the western frontier, and for that matter over the whole infested area, are suppressed. It is from these that the wind spread largely comes about. The longer they can be kept down, the less the likelihood of their becoming a source of infestation to the country beyond.

Especially along the frontier the colonies are at first few and scattered, and while everything within reason will be done toward their suppression, there is believed to be justification for asking the active cooperation of forest owners directly interested. If through a modification in their methods of handling their property they can save themselves from what would now appear in many instances to be certain loss; if they can at the same time put their forests in such condition as not only to protect them in the future but also to render them more intrinsically valuable; and, finally, if they can render a not inconsiderable public service through helping to

retard the progress of the moth into territory not as yet infested, the request for such cooperation would appear to be well justified.

This project, to bring good out of the evil that has resulted through the establishment of the gipsy moth, by combating it through methods which would make American forests more valuable than they have ever been before, is no mere vision. Evidence enough of its practicability in the case of the mixed stands of oak and pine already referred to is easily found and sufficiently convincing. That other types of natural forests may be handled so as to make the outcome advantageous to the forest owner as well as to the whole country, it is only reasonable to expect.

The Forest Service and the Bureau of Entomology will attempt to do their share of the work, through cooperative study of the technical aspects of the problem. Experimental and demonstrative work must precede definite recommendation, and in this the aid and assistance of the forest owners themselves must be secured. If a spirit of hearty cooperation can be established and maintained it would seem as though the problem would all but solve itself.

Approved:

JAMES WILSON,

Secretary of Agriculture.

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